8 Pages
Code 1
Cat 26
N66 27040

NASA TT F-8071
AUG 23 1961
SEP 15 1961
Cat 26

DRAFT TRANSLATION

MOTION PICTURE PHOTOGRAPHY OF VARIATION PROCESSES OF THE DOMAIN STRUCTURE OF THIN FERROMAGNETIC FILMS IN A MAGNETIC FIELD

(Kinofl'mirovaniye protsessov izmeneiya magnitnoy structury tonkikh ferromagnitnykh plenok v magnitnom pole)

Fizika metallov i metallovedenye
T.11, vyp.4, pp. 529-532, 1961

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ABSTRACT

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Changes in the domain structure of thin films of two alloys (50% Fe, 50% Ni and 17% Fe, 80% Ni, 3% Mo) were studied by means of motion picture photography. The films, whose thickness varied from 760-2470 Å, were prepared by thermal deposition of the alloys on a grass plate in a vacuum and an external magnetic field of 100 Oe. Study of the photographs shows that the domain structure of all ferromagnetic films remains stable until the magnetic field reaches some critical value. In relatively thick films, magnetization occurs with intermittent displacement of domain boundaries when the magnetic field reaches a critical value. No boundary displacement was observed in thinner films; their magnetization takes place with the destruction of domain boundaries and, in some cases, with a change in their structure or the appearance of new boundaries.

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A detailed study of the dynamics of thin ferromagnetic film magnetic structure is very important for the understanding of the complex processes taking place at their magnetization or magnetic reversal, namely for the intelli-

gent selection of most appropriate ferromagnetic films for computer and controller storage devices.

During the last few years a series of works appeared, in which the behavior of the domain structure in thin ferromagnetic films is studied. This research was conducted either with the aid of the Kerr magnetooptical effect [1 - 2], or by powder method [3 - 5].

However, the investigations so conducted are far from having disclosed all of the complex picture of thin ferromagnetic film domain structure behavior. Besides, only separate stages of the domain structure's state could be investigated by means of photography, and not the continuous change with the variation of the magnetic field, which may best of all be achieved by means of motion picture photography. [6].

This has been done in the present work with the help of powder figures for thin ferromagnetic films of two alloys - Fe(50%), Ni (50%), and Fe (17%), Ni (80%), Mo (3%).

EXPERIMENTAL PART

The films were obtained by way of thermal spraying of the indicated alloys in a vacuum $7 \cdot 10^{-6}$ mm Hg over optically polished glass with dimensions 1 by 10 by 40 mm, and heated to 350°. A 100 oe magnetic field was applied at time of film obtention.

The alloy introduced in the crucible for evaporation was fully atomized within 30 seconds. This entitles us to assert that the composition of the obtained thin ferromagnetic films may only little differ from the original material.

As the investigations have shown, the direction of the light magnetization in the films coincides with that of the magnetic field at time of film obtention.

The thickness of the films was measured with the help of a universal monochromator YM-2, by means of lines of equal chromatic order [7].

The photographing of the domain structure was carried out by the micro-motion picture equipment MKY-1 in the reflected light.

The domain structure was revealed by the powder method. The speed of picture taking was of 12 frames per second.

RESULTS OF THE INVESTIGATION

Without preliminary demagnetization the domain structure is not revealed on the obtained films, inasmuch as these are magnetized to saturation. The domain structure appears at demagnetization by a variable magnetic field with an amplitude decreasing to zero, and its form depends to a greater degree on the direction of the demagnetizing field in relation to the axis of the light magnetization. In all cases the domain structure becomes finer at the increase of the angle between the direction of the demagnetizing field and the light axis.

The motion picture photography began every time from the state of demagnetization in an increasing magnetic field.

Fig. 1 represents a series of frames from a film fixing the variation of the domain structure of the Fe-Ni alloy's film, 2470 Å thick in a field increasing along the axis of light magnetization.

The original structure is obtained after demagnetization in the same direction. The directions of the axis of the light magnetization and of the applied field are designated by an arrow under the first photograph, and the direction of the magnetization vector in the domains — by arrows on the photograph itself. At the increase of the field to 9.3 oe the domain structure does not vary. This

fact is specific for thin ferromagnetic layers, as in massive ferromagnetics the reversible boundary displacement begins already in quite feeble fields. With a subsequent field increase the boundary displacement begins, the motion velocity of various boundaries being quite different, and the boundary motions not being characterized by smoothness. Saturation is reached in the field with a strength of 17.6 oe, and the domain structure disappears over the whole surface of the film.

Fig. 2 shows the variation of domain structure of a Fe-Ni-Mo alloy's film, 1400 A thick, in a magnetic field directed under the angles of 0 and 90° to the axis of light magnetization. The most characteristics frames were selected from the film, from which the variation of the domain structure may be appraised. The initial structure was obtained by demagnetization under an angle of 45° with the axis of light magnetization. As a result, a relatively finer domain structure was obtained. It must also be noted, that under the same demagnetization conditions, it is difficult to obtain in the same spot a sample of a strictly indentical magnetic structure. This may be seen on first photographs corresponding to the zero field on figures 2 a, and 2 б . The directions of the magnetizing fields are shown under the same photographs. As the field increases to 8.7 (fig. 2a) and to 11 oe (fig. 2), the domain structures remain unchanged. At further increase of the field no boundary displacment is observed in either case, but a domain structure disintegration takes place by way of a sudden collapse and disappearance of boundaries, which apparently is the result of a sudden reverse magnetization of separate domain areas by fast rotation within them of the magnetization vector.

Fig. 3 shows the variation of the domain structure of the Fe-Ni film, 850 A thick in a field applied along the light magnetizatuon axis indicated on the figure by an arrow. The initial structure was obtained by film demagnetization in the same direction.

The domain structure does not vary until the 15.4 oe field strength is reached. At the increase of the field to 16 oe, the domain boundaries remain in their previous positions, but in the domains disadvantageously oriented with respect to the direction of the field, new boundaries appear, which are perpendicularly oriented in respect to the applied field. This apparently takes place because separate parts of the disadvantageously oriented domains underwent the change in the direction of magnetization vector, and the formed "sub-domains" resulted divided by new boundaries.

With the further field increase, a jump-like disintegration of disadvantageously oriented domains takes place until their total disappearance.

Figure 4 shows the variation of the domain structure at magnetization of a 760 A thick alloy Fe-Ni in a magnetic field applied along the light magnetization axis. The demagnetization of the film for the obtention of the domain structure was effected in the same direction.

In a zero field, one may see in the frame domains outlined by boundaries with cross bonds [8]. No domain structure variation is observed until the field reaches the 10.8 oe strength. At further increase of the field strength, the cross bonds begin to disappear, although no basic boundary displacement takes place. In the domains disadvantageously oriented in respect to the field, there appear, as shown on figure 3, cross boundaries mainly developed from a small number of preserved cross bonds. As the field increases further, the disadvantageously oriented domains disnitegrate and disappear completely when the field's strength reaches 14.4 oe.

CONCLUSION

It is naturally difficult to translate all the results of domain structure investigation with the aid of sampling frames, which become particularly obvious and convincing at direct film examination. It is nonetheless absolutely evident

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evident that the magnetization processes in thin ferromagnetic films have certain specific peculiarities in comparison with massive ferromagnetic crystallites. This peculiarity depends essentially on the thickness of ferromagnetic films and on the direction of magnetization.

The peculiarities of thin ferromagnetic film magnetization may be reduced to the following:

1. For all ferromagnetic films till a certain critical field the domain structure is stable.

2. In relatively thick ferromagnetic films the magnetization is realized by boundary displacement which begins at reaching a certain critical field. The boudary displacement itself is not characterised by smoothness.

3. In thinner fils no boundary displacement was observed. The magnetization took place by way of domain structure disintegration, apparently provoked by a sudden turn of the magnetization vector of separate domain areas disadvantageously oriented in relation to the field. The domain structure disintegration also begins at reaching a certain critical field. The magnetization of this films is at times accompanied by the appearance of new boundaries, dividing the disadvantagouely oriented domains in separate "sub-domains", and also by the change in structure of basic boundaries.

***** THE END *****

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Entered for publication
on 10 September 1960.

Translated by Andre L. Brichant
NASA TECHNICAL INFORMATION DIVISION
on 22 August 1961.

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ANNOUNCEMENT OF NEW PAPERS ON THE SUBJECT OF WHICH TRANSLATIONS WILL BE FORTHCOMING

— KIRENSKIY, L. V., BURAVIKHIN, S. V. KAN, S. V., & DEKTYAREV, I. F.
Domain Structure of Thin Ferromagnetic Films. Iz. A N SSSR, Sibirskoye Otd No.5, pp. 3 - 9 , 1961.

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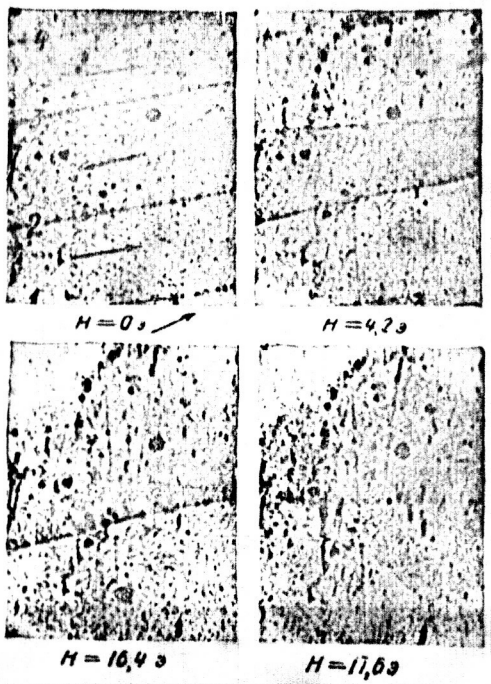

Fig. 1. Boundary displacement between domains in a Fe-Ni film of 2470 A thickness

Fig. 2. Variation of the domain structure on a Fe-Ni-Mo film of 1400 A thickness, in a magnetic field directed at a 0° angle (а), and 90° ( ) with the axis of light magnetization, which is horizontal

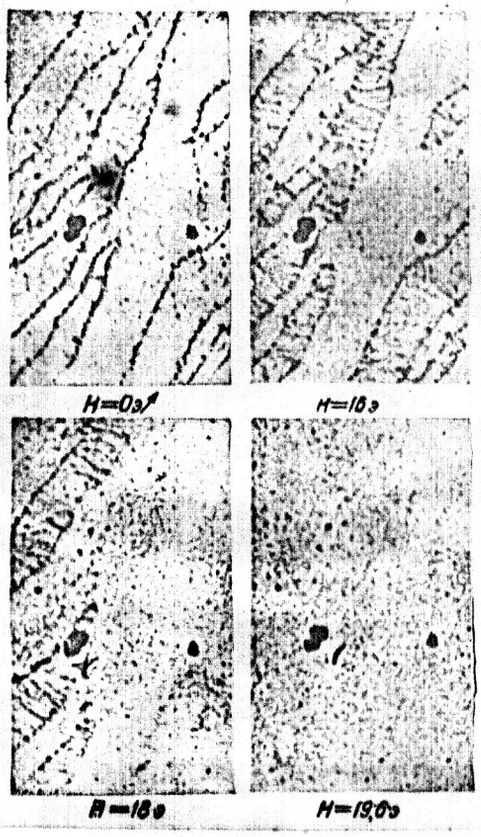

Fig. 3. Variation of the domain structure on a Fe-Ni film of 850 A thickness, in a magnetic field directed along the axis of light magnetization

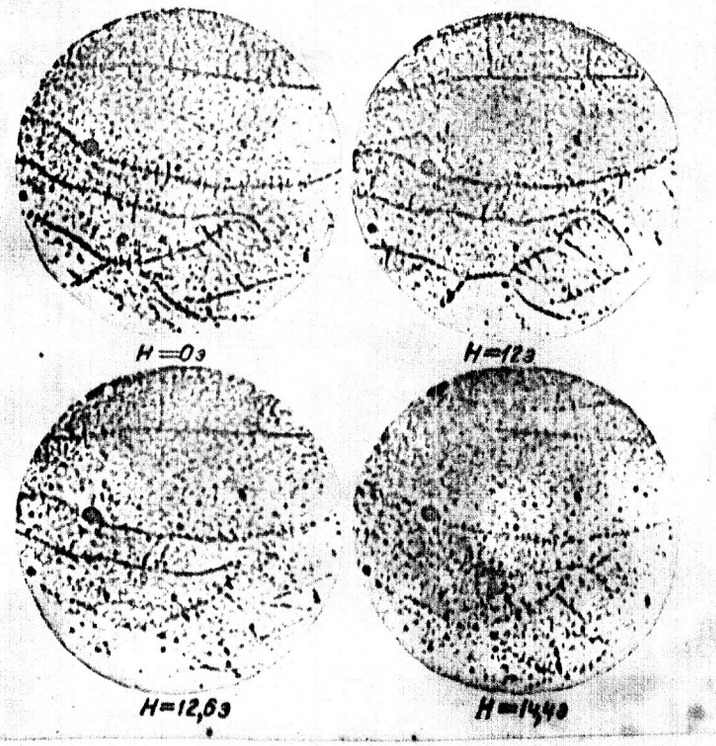

Fig. 4. Boundary and domain structure variation in the Fe-Ni film of 760 A thickness at magnetization along the light axis. The axis of light magnetization is horizontal.